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Outcomes after Cognitive Perceptual Motor Retraining (CPM) of Patients with Acquired Brain Injury (ABI)

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Abstract

Background: Remediation of deficits is one approach used by occupational therapists in the treatment of clients with acquired brain injury (ABI). This retrospective study examined outcomes after participation in Cognitive Perceptual Motor Retraining (CPM) of clients with ABI and identified demographic and injury characteristics of clients that were associated with outcomes. CPM was delivered as part of the standard treatment and was not designed for research purposes.

Method: A retrospective review of 59 client records was completed. CPM evaluation test scores, demographic information, and injury characteristics were extracted from the records.

Results: There were moderate improvements in CPM test scores and good discharge outcomes for most clients. Discharge to home with independent status was associated with mild to moderate traumatic brain injury severity and being married. Longer time since injury and having a concurrent psychiatric diagnosis were associated with longer duration of CPM.

Conclusion: This preliminary study demonstrates positive therapy outcomes after CPM. Recommendations were made for future research and considerations in the use of CPM. These include the need for addressing concurrent needs, such as psychological issues and repeated re-evaluations, to determine when clients have met maximum remediation and thereby minimizing cost.

Comments

Disclosures: Ms. Christy, Ms. Huffine, and Ms. Hannah are all employed by Origami Brain Injury Rehabilitation Center where CPM is administered.

Keywords

occupational therapy, rehabilitation, remediation

Cover Page Footnote

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Occupational therapists are typically part of an interdisciplinary team of professionals involved in the rehabilitation of patients with acquired brain injury (ABI). Many factors determine the goals that occupational therapists establish and the types of services they provide. One important client factor is the potential for change or improvement. According to the *Occupational Therapy Practice Guidelines for Adults with Traumatic Brain Injury* (TBI),

> If the individual with TBI demonstrates potential for improvement in underlying cognitive and motor impairments, shows awareness of current limitations, and shows the ability to alter performance when provided cues and feedback, the occupational therapist may choose to focus intervention on restoring underlying cognitive and motor impairments that contribute to difficulties in the performance of functional tasks (Golisz, 2009, Intervention Addressing Areas of Occupation, para. 5).

The remediation approach uses activities that challenge current abilities, with the therapist providing opportunities for practice using graded tasks in controlled therapeutic settings. Cognitive Perceptual Motor Retraining (CPM; Kulkarni, 1993; Westfall, Moore, Kulkarni, Cook, & de Leon, 2005) is one therapy that uses the remediation approach for rehabilitation of TBI. This approach is systematic and hierarchical in nature, while using a bottom-up approach and repetition.

An Overview of CPM

Occupational therapists use CPM in treatment at the Origami Brain Injury Rehabilitation Center, a post-acute facility providing residential, community-based, and outpatient therapy services for individuals with ABI. Developed by Madhav Kulkarni, Ph.D., OTR., CPM is used for remediation of deficits in cognitive, perceptual-motor, and sensory-motor functioning following brain injury (Westfall et al., 2005). CPM's remedial approach is based on the premise that due to plasticity, the brain can reacquire function through environmental stimulation. Recent evidence for neuroplasticity after cognitive rehabilitation supports the remediation approach to treatment after TBI. Neuroimaging studies have documented changes in brain activation and connectivity during a recognition task (Ueno et al., 2009), visuospatial attention tasks (Kim et al., 2009), and perceptual organization and working memory (Castellanos et al., 2010) after subjects with TBI completed cognitive training.

The CPM therapist and client identify remediation goals at the initial evaluation. CPM postulates that reacquisition of skills must follow the original path of development of brain functions and therefore uses a hierarchical approach to the ordering of the identified goals and corresponding therapeutic activities (Piaget, 1973; Warren, 1993). CPM uses a variety of paper-and-pencil tasks, computerized activities, graduated manipulation of objects, and other activities that have specific remediation goals. CPM treatment tasks are specifically chosen for placing increasing demands on the brain in order to sequentially restore disrupted brain processes (Piaget, 1973). All clients begin with the same sensory-motor and perceptual tasks because these tasks are assumed to precede cognitive processes. Restoration and integration of affected sensory-motor and perceptual skills will ultimately enhance cognition (Ayres, 1975, 2005). In addition, the tasks are initially rudimentary and become more complex as the treatment is successful, with a strong emphasis on repeated practice, mastery of skills, and the reacquisition of competence (Luria, 1970; Piaget, 1973).

Therapeutic activities include those similarly used in cognitive rehabilitation (Cappa et al., 2005; Helmick, 2010), such as process, strategy and functional training activities, errorless learning, and awareness training (Golisz, 2009; Malia et al., 2004; Ueno et al., 2009). Other goals include increasing tactile sensitivity and other visual-spatial, tactile-kinesthetic, and fine motor skills. Several studies provide evidence for successful remediation of deficits after TBI in attention and working memory (Stablum, Umilta, Mazzoldi, Pastore, & Magon, 2007; Westerberg et al., 2007), processing speed (Klonoff et al., 2007), executive functioning (Serino et al., 2007), and visual-spatial deficits (Antonucci et al., 1995; Klonoff et al., 2007; Poggel, Kasten, & Sabel, 2004).

When clients have successfully attained most of the remediation goals, a discharge evaluation is completed to determine status and further recommendations. The remediation process is determined to by complete when the client demonstrates successful performance in the graduated tasks and significant improvements to within the normal range in a battery of tests. Remediation activities can also be terminated when the client is observed to have reached a plateau (i.e., the client is no longer demonstrating gains and continued participation would not be of additional benefit). After remediation, CPM begins the more traditional occupational therapy approach of practicing skills in the environment in which the client will use them. This includes assessing the individual's ability to generalize his or her newly retrained skills to relevant environments such as home, work, or school. In cases when deficits remain after maximal progress has been attained, the therapist and client work on compensatory strategies and identifying alterations to the environment.

CPM is a remediation approach used by occupational therapists. It differs from traditional occupational therapy practice in that it combines therapies that are typically provided by different professionals. These include sensory integration activities, which are provided by occupational therapists, and cognitive remediation, which is more typically addressed by speech and language pathologists and neuropsychologists. This bottom-up approach also differs from the typical occupational performance focus (AOTA, 2008). There is an emphasis on large amounts of repeated practice of basic foundational skills. The reacquisition of skills is evaluated in formal retesting. Similar to occupational therapy practice is the additional evaluation of skills through observations of the client's ability to function in his or her environment through the use of the underlying reacquired skills. For example, improvements in occupational skills (e.g., visual

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scanning during driving simulation and left to right tracking in reading), speed of processing during daily activities (e.g., meal preparation and safety in the community), and mental tracking and sequencing in daily tasks (e.g., dressing or completing learned work tasks).

CPM is typically administered as part of integrated rehabilitation services, which include physical therapy, speech therapy, psychology, and vocational therapy. It is often used as one of the initial therapies that prepare a client for more advanced rehabilitation activities, such as vocational rehabilitation and the return to driving. The improvements following CPM enable patients to engage in more challenging therapies that prepare them for a return to productivity.

Study Objectives

The primary aim of this retrospective study was to examine the outcomes of individuals with ABI after participation in CPM. Specifically, this study (a) compares initial and discharge CPM evaluation test scores and (b) describes the discharge status of clients.

A secondary aim was to identify the clients' demographic and injury characteristics that are associated with outcomes. Demographic characteristics include age, gender, educational attainment, marital status, and work/school status at time of injury. Injury characteristics include brain injury severity and time since injury. Other variables include litigation status and concurrent psychiatric diagnosis.

Method

This retrospective study is a report of outcomes after CPM, which was delivered as part of a standard treatment and was not designed for research purposes. We retrospectively reviewed and analyzed 59 client records. Occupational therapists provided CPM assessments and treatments. The therapists were trained in CPM while they were clinical interns prior to their subsequent hiring. The training typically occurred during a one-semester internship (40 hr per week for 3 months) and involved assigned readings, lectures/discussions on the CPM theoretical framework, initial shadowing of a CPM-trained therapist, testing and treatment laboratory, supervised test administration, treatment and report writing, and weekly meetings to discuss clients and the CPM approach.

We identified clients through the medical records. Clients were eligible for inclusion if they received and had been discharged from CPM services between 1998 and 2009, had initial and discharge CPM evaluations, and were between the ages of 18-64 years. We excluded clients older than 64 years of age because of the increased likelihood of other health issues, such as cardiovascular conditions, arthritis, and mild cognitive decline that may affect cognitive and sensorimotor functioning. We excluded clients who did not speak English in order to exclude poor performance that may be due to a lack of language proficiency. We also excluded clients with other diagnoses indicative of cognitive disorder not due to TBI (e.g., dementia). We had initially included three clients with ABI due to stroke, but excluded them from analysis because of the differences in injury mechanisms (i.e., injury due to occlusion of oxygen rather than injury due to force trauma). We had also initially reviewed three

Table 1
Demographic, Injury, and Therapy Characteristics and Outcomes (N = 53)

Demographic Variable	N	%*
Gender		
Male	**30**	**57**
Female	**23**	**43**
Age Categories		
18 – 29	20	38
30 – 39	9	17
40 – 49	16	30
50 – 59	5	9
60 – 64	3	6
Marital Status		
Single	28	53
Married	18	34
Divorced or separated	7	13
Ethnicity		
Caucasian	41	77
African American	5	9
Hispanic	5	9
Other	2	4
Education		
No high school diploma	10	19
High school graduate or GED		
Some college, no degree	17	32
Associate Degree		
College/Bachelor's Degree	12	23
Master's Degree or higher	6	11
Unknown	3	6
	4	8
	1	2
Pre-injury Work Status		
Working full-time	22	42
Working part-time	12	23
Student	9	17
Not working	10	19
TBI Severity		
Mild	20	38
Moderate	10	19
Severe	23	43
Cause of Injury		
Vehicular (4-wheeled)	40	76
Other vehicular	5	9
Pedestrian	3	6
Fall/hit by moving object	1	2
Assault	1	2
Other	3	6
Time Since Injury		
3 months or less	22	42
4-6 months	10	19
7-11 months	9	17
1 year or more	12	23
Rehabilitation Service		
Residential	14	26
Outpatient	23	43
Day treatment	12	23
Community integration/ semi-independent Living	4	8
CPM Duration		
12 weeks or less	4	8
13-24 weeks	19	36
25-36 weeks	18	34
37-52 weeks	11	21
More than one year	1	2
Reasons for Discharge		
Goals met	40	75
Reached maximum	7	13
remediation	3	6
Transfer to another facility	3	6
Other (loss of funding, other services needed, return to work)		
Discharge Locations		
Home with independent	31	58
status	14	26
Home with recommended supervision	6	11
Transfer to another facility for continued rehabilitation	2	4
Another facility for full supervision		
Work Status at CPM Discharge		
Working full-time	6	11
Working part-time	10	19
Supported employment	6	11
Student	8	15
Not working		
Prevocational activities	8	15
Medical leave or short-	3	6
term disability	12	23
Not working		

Note. Percentages total may not be equal to 100 due to rounding.

client records that we removed from analysis because of dual diagnosis (e.g., electrocution resulting in a fall with TBI). The dual diagnosis made it difficult to attribute the post-injury deficits to TBI alone. The authors included in the analysis 53 of the 59 records that were reviewed. Three of the authors were involved in administering CPM and associated assessments to some of the clients in the sample. The first author, who had no contact with any of the clients, conducted the identification of clients, data extraction from the medical records, and data coding for statistical analyses.

The Biomedical and Health Institutional Review Board of Michigan State University (MSU) approved the research protocol. Because we had no contact with clients throughout the conduct of this study, we received a waiver of authorization from the MSU Research Privacy Board.

The sample represented clients with varying time since injury through stratified random sampling based on proportions obtained through a preliminary analysis of medical records from 1998 to 2009 (i.e., 77% of all clients seen at the facility were less than a year postinjury and 23% more than a year postinjury). Table 1 summarizes the demographic and injury characteristics of the clients.

The mean age of the clients was 35.8 $\pm$ 1.9 years (SD = 13.7, Median = 36.0). Most of the clients were working at least part-time at the time of the injury (61%). TBI severity ranged from mild to severe. We determined brain injury severity based on the VA/DoD Clinical Practice Guideline (Department of Veteran Affairs, 2009) using a combination of information, such as the Glasgow Coma Scale (GCS) score, length of loss of consciousness (LOC), and/or post-traumatic amnesia (PTA). The criteria used were: (a) mild TBI – GCS 13-15, LOC $\leq$ 30 min, PTA $\leq$ 1 day, (b) moderate TBI – GCS 9-12, LOC > 30 min, < 24 hr, PTA >1 day, < 7 days, and (c) severe TBI – GCS < 9, LOC > 24 hr, PTA > 7 days. Median time since injury was five months. Duration of CPM varied from 7 to 58 weeks (27.0 $\pm$ 1.5, SD = 10.8, Median = 27.0 weeks). Most of the clients received multiple services, most commonly psychology, speech-language pathology, and vocational rehabilitation.

Main Outcome Measures

The main outcomes examined were changes in CPM evaluation test scores and the discharge status of clients.

CPM tests. The CPM battery of tests includes standardized assessments of cognitive, perceptual, and motor functions. Although tests are classified into subsections based on the primary skills to be assessed, these skills are interdependent. Several tests overlap into other areas of function. The CPM battery includes tests of visual-spatial and tactile-kinesthetic perception, motor functions, and cognition. For this study, we selected a subset of tests that represent evaluations of perceptual, hand motor, and cognitive functions. Table 2 lists the tests and norms used.

The perceptual portion of the CPM battery is divided into tactile-kinesthetic and visual-spatial. The tests of tactile-kinesthetic perception, Graphesthesia and Manual Form Perception, assess proprioception and kinesthesia and higher-level skills, such as tactile-kinesthetic memory, tactile-kinesthetic discrimination, stereognosis, and tactile-kinesthetic processing speed.

The tests of visual-spatial perception include Cancellation of H, Alternating Dot-to-Dot, and Minnesota Spatial Relations. These tests assess visual attention (focused, shifting, and selective), visual scanning, visual sequencing, figure-ground perception, size and shape discrimination, visual matching, depth perception, visual organization, and visual-spatial processing speed. Tests of motor functioning included the Slosson Copying and Purdue Pegboard. These tests assess manual motor functioning, which includes motor planning, motor control, gross motor coordination, fine motor coordination, hand/eye coordination, bilateral coordination, motor sequencing, and motor speed. Grip strength, in pounds, was assessed using a standard adjustable-handle Jamar Dynamometer.

Table 2
Tests Used in the CPM Evaluation

Tests	Protocol Source	Norms Used
Tactile-Kinesthetic		
Graphesthesia subtest of the Southern California Sensory Integration Test (SCSIT)	Ayers, 1975	Hsu & Nelson, 1981
Manual Form Perception subtest (SCSIT)	Ayers, 1975	Hsu & Nelson, 1981
Visual-Spatial		
Cancellation of H	Kulkarni et al., 2013	Kulkarni et al., 2013
Alternating Dot-to-Dot	Kulkarni et al., 2013	Kulkarni et al., 2013
Minnesota Spatial Relations	Dawis, 1979	Dawis, 1979
Motor		
Slosson copying of the Slosson Visual Motor Performance Test	Slosson, 1996	Slosson, 1996
Purdue Pegboard	Tifflin, 1948	Desrosiers et al., 1995; Yeudall et al., 1986
Grip strength	Mathiowetz et al., 1985	Mathiowetz et al., 1985
Cognitive		
Object Sequence of the Detroit Tests of Learning Aptitude-2 (DTLA-2)	Hammill, 1985	Hammill, 1985
Letter Sequences of the DTLA-2	Hammill, 1985	Hammill, 1985
Symbol Digit Modalities Test	Smith, 1991	Smith, 1991
Arithmetic subtest of the WRAT-3/WRAT-4	Wilkinson, 1993; Wilkinson & Robertson, 2006	Wilkinson, 1993; Wilkinson & Robertson, 2006

The Symbol Digit Modalities Test assesses attention, short-term visual memory, encoding and decoding of information, and incidental and intentional learning. The Arithmetic subtest of the Wide Range Achievement Test assesses logical quantitative reasoning and arithmetic calculations. CPM therapists have been using the Object Sequences and Letter Sequences of the Detroit Tests of Learning Aptitude – 2 (DTLA-2; Hammill, 1985) to assess short-term visual and linguistic memory. These tests have since been replaced. However, for this study, we included DTLA-2 scores because of the inclusion of older records.

Discharge status. We assessed discharge status in several ways: (a) percentage of goals met, (b) discharge location, (c) reasons for discharge, (d) productivity status at time of discharge, and (e) duration of CPM. The percentage of goals met was calculated based on the number of goals achieved prior to discharge compared to the number of goals set at the initial evaluation by the therapist and the client. Typically, three long-term goals were set in each of the overarching treatment areas, including visual perceptual, tactile kinesthetic/motor, and cognitive perceptual skills. Treatment objectives were made specifically in each long term goal area, incorporating various session activities based on information gathered from initial evaluation and standardized assessment scores. For example, a therapist could establish the objective to independently complete a tactile-input and tactile-output 17-peg display with 100% accuracy on the Tactile Kinesthetic Pegboard to address the long-term goal in tactile kinesthetic and motor perception skills. Once objectives were met or plateaued, retesting occurred to determine if the long-term goals were met. Clinical reasoning is heavily involved in setting session treatment objectives and determining plateau status.

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The discharge location was categorized according to the site to where the client was moving after discharge from CPM. It also included the client's level of supervision because it is possible for clients to be discharged to the same location type but with varying degrees of supervision needed. Discharge locations included home with independent status, home with some supervision, home or another facility with full supervision, and/or another facility to continue rehabilitation.

Reasons for discharge from CPM services included: goals have been met, maximum remediation has been achieved, or CPM was not completed due to other reasons. Goals were considered met when the client had demonstrated improvements on re-evaluation to the level of initial established goals. For example, "Visual perceptual skills will improve into the low average range as determined by the Developmental Tests of Visual Perception in figure-ground perception, visual closure, and form constancy." Clients should have also shown a return to some form of productivity and improved independence for met goals. In cases when the client has not met all of the goals and was no longer showing improvements, the client was determined to have achieved maximum remediation.

Duration of CPM treatment was measured in terms of weeks from the initial evaluation to discharge from CPM. At this rehabilitation facility, client progress is assessed at weekly meetings and the anticipated duration of treatment for each service is determined in terms of number of weeks.

Demographic and injury characteristics as correlates. Demographic variables included age, gender, race, education, pre-injury work status, TBI severity, and marital status.

Data Analyses

The Statistical Package for the Social Sciences, SPSS versions 17 and 19 for statistical calculations (IBM, 2010; SPSS, 2008) was used for all data analyses. Two-tailed tests of significance were calculated with alpha set at .05. Descriptive statistics, such as mean scores, standard deviations, and standard error summarized demographic and injury characteristics. The median was also reported when distributions were skewed. The 95% confidence interval was calculated when appropriate.

We analyzed the distribution of scores using the Kolmogorov-Smirnov and Shapiro-Wilk (SPSS) tests of normality and a visual examination of histograms. This analysis showed non-normal distributions of most of the test scores. Therefore, we used the nonparametric Wilcoxon signed-ranks test to compare initial and discharge CPM evaluation test scores. We calculated effect size for the Wilcoxon test using the formula $r = |Z| / \sqrt{N}$, where Z is the approximation of the Wilcoxon statistic, and N is the number of observations x 2 (Cohen, 1988; Grissom & Kim, 2005). Cohen (1988) recommends a cut-off of .30 to signify a medium effect and .50 to signify a large effect.

To determine associations between discharge status and demographic and injury characteristics of clients, we used a variety of tests depending on the data level: Pearson r when both variables were interval level (e.g., time since injury in months and percentage of goals met), Chi Square tests of independence or the Fisher test when both variables were categorical (e.g., TBI severity and discharge to home with independent status), and the Mann-Whitney U test when one variable was categorical and the other variable was interval level (e.g., has a psychiatric diagnosis and duration of CPM in weeks).

Results

We examined outcomes after participation in CPM by clients with TBI. We also identified client characteristics that were associated with discharge outcomes.

Comparison of Initial and Discharge Evaluation Test Scores

Table 3 summarizes the CPM test scores at the initial and follow-up evaluations. There were significant improvements in almost all test scores except for the Slosson Copying subtest. Using Cohen's recommended cut-off values of r = .30 for medium and r = .50 for large effect sizes, 15 of the 19 tests showed medium effect size and three showed large effect size.

Differences in change scores according to injury characteristics. Examination of demographic and injury characteristics revealed that change scores tapered off with increasing time since injury (see Table 4). Those who participated in CPM within six months of their injury significantly improved in all tests. Those who participated within 7-11 months of injury improved in 58% of tests, and those who participated a year or more postinjury improved in 50% of tests. Although gains were made in fewer tests for those with more remote injuries, effect sizes were moderate to strong for these groups as well.

Injury severity showed an unpredictable pattern of change scores (see Table 5). Both those with mild or severe TBI showed significant improvements in more test scores (79% and 89% of test scores, respectively) than those with moderate TBI (58%). This finding may be due to the relatively small sample of moderate TBI clients (N = 10), which requires larger differences between scores to reach statistical significance. The results show that even those with severe TBI had significant improvements at re-evaluation.

Table 3

Comparison of Pre and Posttest Scores on CPM Evaluation Battery

	N[1]	Pre-CPM M (SD)	Pre-CPM Median	Post-CPM M (SD)	Post-CPM Median	Wilcoxon Z^2	p	r (effect size)
Tactile Kinesthetic								
Graphesthesia Right Hand	41	8.1 (3.0)	9.0	9.4 (2.2)	10.0	3.06	.002	.341
Graphesthesia Left Hand	41	8.3 (2.7)	8.0	9.8 (1.8)	10.0	3.50	.001	.390
Manual Form Adjusted Score	48	6.4 (3.0)	7.0	7.8 (2.8)	9.0	4.44	.000	.453
Visual-Spatial								
Figure-Ground Total	46	33.6 (5.7)	34.0	37.4 (5.8)	38.0	4.13	.000	.431
Cancellation of H (seconds)	57	90.0 (40.7)	83.0	77.5 (27.8)	70.0	3.61	.000	.335
Alternating Dot-to-Dot (seconds)	49	65.4 (39.5)	55.0	44.8 (28.6)	40.0	4.61	.000	.471
Minnesota Spatial Relations (score)	42	676.0 (196.2)	610.8	521.8 (145.5)	990.5	5.10	.000	.557

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Motor								
Slosson Copying	35	26.1 (8.3)	27.0	29.5 (7.3)	32.0	2.42	.016	.289
Purdue Pegboard Dominant Hand	56	12.3 (3.6)	12.5	14.3 (3.1)	15.0	5.14	.000	.482
Purdue Pegboard Nondominant Hand	54	11.5 (3.5)	11.5	13.3 (3.2)	13.5	5.70	.000	.549
Purdue Pegboard Both	55	9.3 (3.1)	10.0	10.9 (2.9)	12.0	4.88	.000	.465
Purdue Pegboard Assembly	53	25.2 (9.2)	25.0	30.5 (9.8)	32.0	5.00	.000	.486
Grip strength Dominant Hand	48	58.6 (32.4)	58.0	71.4 (31.2)	73.0	3.88	.000	.397
Grip strength Nondominant Hand	46	59.2 (33.0)	53.5	69.9 (30.1)	68.0	4.16	.000	.434
Cognitive								
DTLA-2 Object sequences	40	37.9 (7.9)	39.0	44.1 (7.0)	45.5	4.27	.000	.477
DTLA-2 Letter sequences	36	47.5 (11.4)	51.0	50.9 (9.1)	52.5	2.66	.008	.314
SDMT-Written	56	35.3 (13.6)	38.5	46.7 (12.0)	49.0	6.29	.000	.594
SDMT-Oral	53	40.4 (15.4)	41.0	50.3 (15.9)	53.0	4.77	.000	.463
WRAT-3	43	35.0 (7.2)	36.0	38.7 (6.9)	40.0	4.19	.000	.453

Note. [1]N (sample size) varies because tests where clients scored within the normal range at initial testing were not readministered at the completion of CPM.
[2]Based on Wilcoxon signed ranks of raw scores.
Abbreviations: DTLA-2 (Detroit Test of Learning Aptitude, 2nd edition), SDMT (Symbol Digit Modalities Test), WRAT-3/4 (Wide Range Achievement Tests, 3rd and 4th editions).

Table 4

Effect Size and P Values of Change in Pre and Posttest Scores on CPM Tests by Time Since Injury

	0 – 6 months postinjury				7 – 11 months postinjury				≥ 12 months postinjury			
	N[1]	Z[2]	p	r[3]	N	Z	p	r	N	Z	p	r
Tactile Kinesthetic												
Graphesthesia Right Hand	25	3.288	.001	0.465	8	0.105	.916 NS	0.026	3	0.447	.655 NS	0.182
Graphesthesia Left Hand	25	2.738	.006	0.387	8	0.420	.680 NS	0.105	3	0.114	.655 NS	0.182
Manual Form Adjusted Score	26	3.499	.000	0.485	9	2.226	.026	0.525	8	2.549	.011	0.637
Visual-Spatial												
Figure-Ground Total	29	3.272	.001	0.430	7	2.371	.010	0.634	5	1.625	.104 NS	0.514
Cancellation of H (seconds)	32	2.506	.012	0.313	9	2.192	.028	0.517	10	2.090	.037	0.467
Alternating Dot-to-Dot (seconds)	29	3.687	.000	0.484	8	2.521	.012	0.630	7	2.366	.018	0.632
Minnesota Spatial Relations (score)	24	4.200	.000	0.606	8	2.521	.012	0.630	6	1.992	.046	0.575
Motor												
Slosson Copying	21	2.173	030	0.335	5	0.730	.465 NS	0.231	5	1.753	.080 NS	0.554
Purdue Pegboard Dominant Hand	30	4.396	.000	0.568	9	1.372	.170 NS	0.323	11	1.965	.049	0.419
Purdue Pegboard Nondominant Hand	28	4.046	.000	0.541	9	2.588	.010	0.610	11	2.812	.005	0.600
Purdue Pegboard Both	29	4.423	.000	0.581	9	2.232	.026	0.526	11	1.901	.057 NS	0.405
Purdue Pegboard Assembly	28	3.465	.001	0.463	8	1.572	.116 NS	0.393	11	2.705	.007	0.577
Grip strength Dominant Hand	28	3.379	.001	0.452	9	1.841	.066 NS	0.434	5	0.674	.500 NS	0.213
Grip strength Nondominant Hand	26	3.811	.000	0.528	9	2.176	.030	0.513	5	0.405	.686 NS	0.128
Cognitive												
DTLA-2 Object sequences	23	3.091	.002	0.456	7	2.214	.027	0.592	5	1.761	.078 NS	0.557
DTLA-2 Letter sequences	21	2.376	.018	0.367	6	0.406	.684 NS	0.117	4	1.289	.197 NS	0.456
SDMT-Written	32	4.882	.000	0.610	7	2.371	.018	0.634	11	2.851	.004	0.608
SDMT-Oral	30	2.267	.001	0.422	7	2.366	.018	0.632	10	2.193	.028	0.490
WRAT-3	26	3.950	.000	0.548	7	0.530	.596 NS	0.142	5	1.753	.080 NS	0.554

Note. [1]N (sample size) varies because tests where clients scored within the normal range at initial testing were not readministered at completion of CPM.
[2]Z is based on Wilcoxon signed ranks test.
[3]r = effect size

Table 5

Effect Size and P Values of Change in Pre and Posttest Scores on CPM Tests by TBI Severity

	Mild TBI				Moderate TBI				Severe TBI			
	N[1]	Z[2]	p	r[3]	N	Z	p	r	N	Z	p	r
Tactile Kinesthetic												
Graphesthesia Right Hand	13	2.192	.028	.430	8	0.272	.785 NS	.068	15	2.424	.015	.443
Graphesthesia Left Hand	13	2.410	.016	.473	8	0.674	.500 NS	.169	15	1.561	.118 NS	.285
Manual Form Adjusted Score	16	2.504	.012	.443	9	2.130	.033	.502	18	3.551	.000	.592
Visual-Spatial												
Figure-Ground Total	15	2.798	.005	.511	10	2.502	.012	.559	16	2.310	.021	.408
Cancellation of H (seconds)	20	1.157	.247NS	.183	10	1.172	.241 NS	.262	21	3.875	.000	.598
Alternating Dot-to-Dot (seconds)	18	3.376	.001	.563	9	1.955	.051 NS	.461	17	2.864	.004	.491
Minnesota Spatial Relations (score)	15	2.812	.005	.513	8	2.521	.012	.630	15	3.408	.001	.622
Motor												
Slosson Copying	10	1.011	.312 NS	.226	7	0.530	.596 NS	.142	14	2.230	.026	.421
Purdue Pegboard Dominant Hand	19	3.275	.001	.531	9	2.539	.011	.598	22	2.981	.003	.449
Purdue Pegboard Nondominant Hand	19	3.589	.000	.582	9	2.232	.026	.526	20	3.634	.000	.575
Purdue Pegboard Both	19	3.320	.001	.539	9	1.983	.047	.467	21	3.172	.002	.489
Purdue Pegboard Assembly	17	2.109	.035	.362	9	1.969	.049	.464	21	3.727	.000	.575
Grip strength Dominant Hand	15	2.901	.004	.530	9	0.140	.888 NS	.033	18	2.984	.003	.497
Grip strength Nondominant Hand	15	2.261	.024	.413	8	1.680	.093 NS	.420	17	3.101	.002	.532
Cognitive												
DTLA-2 Object sequences	14	3.116	.002	.589	7	1.270	.204 NS	.339	14	2.293	.022	.433
DTLA-2 Letter sequences	13	1.533	.125 NS	.301	6	1.897	.058 NS	.548	12	1.649	.099 NS	.337
SDMT-Written	16	2.778	.005	.491	7	2.117	.034	.566	15	2.396	.017	.437
SDMT-Oral	19	3.422	.001	.555	10	2.807	.005	.628	21	4.016	.000	.620
WRAT-3	18	1.570	.116 NS	.262	10	2.668	.008	.597	19	3.545	.000	.575

Note. [1]N (sample size) varies because tests where clients scored within the normal range at initial testing were not readministered at completion of CPM.
[2]Z is based on Wilcoxon signed ranks test.
[3]r = effect size

Other Discharge Outcomes and Associated Characteristics

We analyzed other discharge outcomes, such as duration of participation in CPM, percentage of goals met, locations of and reasons for discharge, and productivity status at the time of discharge. For this paper, discharge refers to termination of CPM services rather than to the release from all or other rehabilitation services.

Duration of participation in CPM. The mean duration of CPM was 27.0 ± 1.5 weeks (SD = 10.8, Median = 27.0 weeks, 95% CI = 24.0 – 29.9). There was a significant difference in CPM duration between those with and without a psychiatric diagnosis (Mann-Whitney U = 206.5.5, p = .019, effect size r = .323). Those with a concurrent psychiatric diagnosis participated in CPM approximately seven weeks longer than those who did not have a psychiatric diagnosis (with psychiatric diagnosis: 29.9 ± 1.9 weeks, SD = 10.9, 95% CI = 26.0 – 33.8, without psychiatric diagnosis: 22.5 ± 2.0 weeks, SD = 9.3, 95% CI = 18.3 – 26.7). None of the other injury or demographic characteristics were significantly associated with CPM duration.

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Percentage of goals met and readiness for discharge. CPM therapists and clients identified goals for remediation after the initial evaluation. Therapists partially determined readiness for discharge from CPM through the client's successful completion of the initial goals. Clients met a mean of 78.7 ± 3% of initial goals (SD = 16.8, Median = 81.8%, 95% CI = 74.0 – 83.4). None of the demographic or injury characteristics were significantly associated with percentage of goals met.

Forty clients (75.5%) were discharged because they had demonstrated significant gains on retesting and had resumed occupations. Seven clients (13.2%) were discharged even though they did not complete the set goals because the therapists determined that these clients had achieved maximum remediation and no additional progress was anticipated. For the latter clients, CPM therapists shifted focus from remediation to the teaching and practice of compensatory strategies and environmental accommodations through traditional occupational therapy practice. This may have been completed by the treating therapist or transferred to another occupational therapist for community-based functional therapy.

Table 1 lists other reasons for premature discharge without completing CPM. These include transfer to another facility, termination or loss of funding, and the need to address a medical or psychiatric issue before continuing therapeutic services.

Discharge locations. Table 1 lists the locations to where clients moved at the completion of CPM. Most clients were discharged to their homes, although approximately a third were recommended to have some initial supervision. Six (11.3%) were transferred to another facility for continued rehabilitation. Only two (3.8%) were discharged to either a nursing home or adult foster care facility with recommended full supervision.

Marital status, time since injury, and TBI severity were moderately associated with being discharged to home with independent status. However, partial correlations analysis showed that only TBI severity remains associated with discharge status after partialling out the contributions of the other variables. Clients were more likely to be discharged to home with independent status if they had mild or moderate TBI. Significantly fewer clients with severe TBI (34.8%) were discharged to home with independent status compared to 81.8% of those with mild TBI and 73.7% with moderate TBI (Chi Square = 9.60, df = 2, p = .008, Cramer's V = .426). There were no significant associations between discharge to home with independent status and the other demographic variables (age, education, and pre-injury work status) and litigation status.

Productivity at discharge. Of the 43 clients who were working or in school prior to injury, 28 (65%) had resumed or attained productive activity at the time of discharge. Seven (16%) were still engaged in vocational rehabilitation activities in preparation for either finding new employment or returning to their previous employment. Three (7%) were on medical leave or on short-term disability. Eight (18.6%) were unable to resume work. None of the demographic or injury characteristics were significantly associated with resuming productive activity. Further examination of individual records focused on the return to work full- or part-time, the place of employment, and accommodations, if any, provided by the employer. This post-hoc examination of individual outcomes showed a greater tendency for employers to provide more flexibility to employees who were working full-time at the time of their injury, including allowing a medical leave of absence and a gradual return to employment accompanied by reasonable accommodations to facilitate an earlier return.

Discussion

As part of an interdisciplinary team's plan of care for individuals with brain injury, CPM is used as one of the initial therapies that aim at restoring tactile-kinesthetic, visual-spatial, manual motor, and cognitive skills lost to injury. This retrospective study examined the status of clients with TBI at the point of discharge from CPM. There were improvements in test scores from the initial and discharge evaluations. Those who were within six months postinjury improved in more tests than those 7-11 months and 1 year or more postinjury. Progress was more modest with those who participated in CPM more than six months after injury. However, effect sizes remained moderate to strong in tests that improved. Studies have demonstrated the importance of environmental enrichment in the post-acute or chronic stages of TBI, with either continued improvement (Frasca, Tomaszczyk, McFadyen, & Green, 2013) or prevention of neural atrophy and consequent decline (Miller, Collela, Mikulis, Maller, & Green, 2013).

The improvements after CPM enabled clients to engage in more challenging therapies, such as vocational therapy, that prepare them for a return to productivity. At the completion of CPM, more than half of the clients were engaged in productive activity, such as return to employment, had returned to previous employment, started a new job, or returned to school. There were some who were not ready to return to work at the time of discharge from CPM but were engaged in prevocational activities, such as participation in vocational rehabilitation. None of the injury or demographic variables were associated with return to work or school. The ability or opportunity to return to work may be a combination of different factors that affect individuals specifically. One such factor is employer support.

Another positive outcome of CPM is discharge to home with independent status. More than half of the clients attained this goal. One-fourth were discharged to home but initially with some supervision. TBI severity was associated with this outcome. Fewer clients with severe TBI were deemed to have the ability to regain independent status. For these clients, maximum remediation was reached in CPM, and additional significant progress was not anticipated. For two of the clients, full supervision was recommended at either a nursing home or an adult foster care facility, and environmental modifications were also recommended to enable these clients to have as much independence as their persisting deficits allowed.

Conversely, there were variables that interfered with progress in CPM during the course of this study. For example, having a psychiatric diagnosis and the severity of the TBI prolonged

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provision of CPM and likely of rehabilitation in general. When psychiatric issues arise, CPM is occasionally placed on hold while these issues are addressed. Not surprisingly, those with severe TBI needed longer rehabilitation services. Maximum remediation was observed in 13% of the clients with severe TBI. Careful monitoring of such clients through more frequent follow-up assessments would ensure that continued progress is being made. When progress is observed to plateau, CPM can then more quickly switch from remediation activities to the teaching of compensatory strategies and environmental accommodations.

Study Limitations

There are limitations due to the retrospective nature of the study. This study examined CPM as typically delivered in the framework of a team. Concurrent therapies do occur, and it is, therefore, difficult to identify how much of the client's progress is specifically due to CPM, especially in areas that overlap with other therapies. However, progress was also observed in areas that are uniquely addressed by CPM (e.g., tactile-kinesthetic and visual-spatial skills). It is also possible that spontaneous recovery may have occurred. However, the considerable time that had elapsed since injury for some of the clients demonstrates that improvements could be observed even past the time when spontaneous recovery could be expected. In addition, the moderate to strong effect sizes suggests that more than spontaneous recovery was likely in effect. Castellanos and colleagues (2010) have demonstrated changes in neural connectivity after participation in a neurorehabilitation program by clients who were on average three months postinjury. The brain changes were associated with improvements in neuropsychological tests. Animal models have also demonstrated the enhancement of spontaneous neural restoration by external stimulation (Wieloch & Nicolish, 2006). A review of neuroimaging studies on brain plasticity after brain injury shows that rehabilitation can interact with spontaneous factors as part of the recovery process (Chen, Epstein, & Stern, 2010).

CPM treatment begins with a prescribed set of activities and proceeds hierarchically. The length of treatment depends on the speed of client progress. CPM is also constantly evolving. Some of the tests included in this study are no longer used because of the lack of norms that are appropriate for adults with brain injury. The weakness of a lack of appropriate norms for the DTLA-2 warrants caution in interpreting results based on these two subtests.

Implications and Recommendations

Results of this study are useful for CPM practitioners to evaluate current practices in the administration of CPM. Identification of psychiatric issues at the initial evaluation is recommended, as such issues may interfere with the client’s ability to benefit from CPM or any other therapy. The VA/DoD practice guidelines for treatment of TBI emphasize the interactions between physical, cognitive, and psychological symptoms and recommend that the presence of comorbid psychiatric conditions should be treated aggressively. We recommend regular follow-up assessments so therapists can more quickly identify when maximum remediation has been achieved. When clients are unable to remediate all skills, they should then shift focus from remediation to compensation. This ensures maximal and cost-effective use of CPM.

We acknowledge that these results are preliminary and recommend additional research, particularly using prospective designs that include a control or comparison group. The results of this study can be used in determining which variables are important to include and control in future studies. This study showed that although most clients did benefit from CPM, a small number experienced limited benefits. Identification of additional client personal factors could help in the development of criteria for initiation of CPM. There is a need, for example, to identify the minimum level of cognitive, perceptual, and motor skills that will allow the client to maximally benefit from participation in CPM. Knowledge of such factors can be used to determine if clients are ready or appropriate for a remediation type of therapy. According to the guidelines for occupational therapists (Golisz, 2009), remediation may be considered when clients show the potential for improvement, awareness of current limitations, and the ability to benefit from feedback. In addition, supportive environments, such as the home, work, or school, may facilitate therapeutic success. This study shows that there are positive outcomes after participation in CPM. We also recognize the role of multiple factors contributing separately or in conjunction with CPM to successful rehabilitation after brain injury.

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